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SESSION A
AIR QUALITY RESEARCH

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Introduction

Environment Ontario holds its annual Technology Transfer Conference to report and publicize the progress made on Ministry-funded projects. These studies are carried out in Ontario Universities and by private research organizations and companies.

The papers presented at Technology Transfer Conference 1988 are published in five volumes of conference Proceedings corresponding to the following sessions:

SESSION A: AIR QUALITY RESEARCH
SESSION B: WATER QUALITY RESEARCH
SESSION C: LIQUID AND SOLID WASTE RESEARCH
SESSION D: ANALYTICAL METHODS
SESSION E: ENVIRONMENTAL ECONOMICS

This volume is comprised of presentations given during Session A of the conference.

For reference purposes, indices for sessions B,C,D and E may be found at the back of this volume, listed in alpha-numeric order.

For further information on any of the papers, please contact either the authors or the Research and Technology Branch at (416) 323-4574 or 323-4573.

Acknowledgements

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SESSION A: AIR QUALITY RESEARCH

Oral Presentations

Abstract

SESSION A: AIR

Oral Presentati

A3

A Numerical Decline Index Rating System to Monitor Changes in Tree Condition of Hardwood Forest Species

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The Problem: Rating the health/decline status of forest trees.

Forest decline has become a serious and contentious issue in many parts of the world. Coniferous forests are affected in Europe, in parts of California and at high elevations in the mountains of the NE US (1,2,4,6,10,11). To date no incidence of coniferous forest decline has been reported in Canada. However, decline in Canadian deciduous forest tree species, particularly sugar maple (Acer saccharum Marsh) is widespread in southern Quebec (3). Recently sugar maple decline has also been reported in Ontario, to a lesser extent in New Brunswick, and sporatically the NE US (9). Decline of deciduous trees in Europe has also been reported, although the extent and severity is marginal relative to the effects observed in the coniferous forests.

There are presently more than 180 theories on the causes of forest decline, which illustrates the complexity and hints at the contentiousness of the phenomenon (5). However, regardless of the causes, all forest decline episodes have a common factor. This factor is the deterioration of the condition of individual trees. Consequently, individual tree condition assessment is required to document the severity of the problems in specific locations or regions. Most tree rating systems are subjective and the assessment parameters are broad. A common approach is to categorize the degree of crown defoliation; e.g. <10%, 11%-25%, 26%-50%, and >50%. Another frequently used rating system assigns a numerical value to the

tree which approximates a decline gradient; e.g. 1 to 5 or 1 to 10, usually with the lowest number equivalent to a tree with no symptoms and the highest number representing a dead tree.

The various rating systems are mostly qualitative, nondescriptive and have a relatively poor resolution. Therefore subtle changes in tree condition cannot be measured, thereby severely limiting the value of the data for detecting trends. However, the greatest shortcoming is that the numerous different rating systems in use are not standardized making it impossible to directly compare the forest decline status between regions or countries.

When the decision was made in 1984 to initiate deciduous tree decline studies in Ontario, it was considered imparative that a rating system be developed which was quantitative, reproducable, and had a narrow confidence interval within a large gradient so that subtle differences could be detected. A high resolution, quantitative rating system was necessary so that regional differences in Ontario's deciduous forest could be recognized and to facilitate accurate trend detection analysis. The method developed to rate the health/decline status of Ontario deciduous trees was called the Decline Index.

How the Decline Index Works

In Ontario the symptoms most often observed in declining sugar maple trees are dieback of the fine branch structure, pale green or chlorotic foliage, and leaves which are distinctly undersized. These three descriptive crown parameters are individually assessed and then combined in a weighted formula which yields a numerical Decline Index (DI) value ranging from 0 (a healthy tree with no symptoms) to 100 (a dead tree). The DI formula is:

$$DI = DB + (A * UL) + (A * ST) + (A * SL/2)$$

where DI = decline index

DB = per cent dead branches

UL = per cent undersized leaves

ST = per cent strong chlorosis

SL = per cent slight chlorosis

A = (100 - DB)/400

Laminated field assessment templates were prepared which illustrate a series of deciduous tree crown silouettes in 10% decline gradients (i.e., 0% full crown, 10% defoliation, 20% defoliation ... 100% defoliation or dead tree crown). On the reverse side of the template are three series of colour chips. Each of the the three series contains 6 chips chosen to illustrate the range of foliar colour encountered in sugar maple in Ontario. One series represents normal green foliage, the second represents pale green or slightly chlorotic foliage and the third series illustrates the colour range considered to be strongly chlorotic.

With the assistance of the prepared silouettes on the laminated field template an evaluator who has been trained in the recognition of typical decline symptoms in Ontario, subjectively estimates, to the nearest 10%, the amount of crown branch dieback, slight and strong chlorosis and undersided leaves. This information is recorded on a tally sheet and the data is later transcribed to a spreadsheet file where the DI is automatically calculated.

Table 1 summarizes the DI for ten trees ranging in decline status from healthy to severe. In this example data set healthy trees had a DI ranging from 0 to 4, trees with light decline symptoms had a DI of 11 to 13, moderately declining sugar maple trees ranged from 22 to 25, severely declining trees had a DI betweem 40 and 45 and the DI of very severely declining trees ranged from 50 to 74. This example data set readily identifies the usefulness of the DI method; whereas the division of trees into ambiguous decline classes based on a subjective assessment is arguable (i.e. is the tree lightly, moderately or

severely declining), the difference between the corresponding mean DI for each of these four classifications, (i.e. light = 12, moderate = 24, severe = 43 and very severe = 62), is quantified.

This example data set also illustrates another important component of the DI method, that is, the foliar parameters in the DI formula are weighted proportional to the live crown. Therefore, trees with a relatively low percentage of branch dieback can have an elevated DI if a large percentage of the living crown is chlorotic and the foliage undersized. This is important for two reasons; 1) foliar abnormalities are usually an early warning of crown dieback and 2) foliar characteristics usually change much quicker than branch structure. This adds an additional degree of sensitivity to the DI. Drawing again on the example data set in Table 1, the first three trees all have no crown branch dieback yet the resultant DI's are 0, 4 and 11 respectively. The difference is a progressive increase in the percentage of foliar chlorosis and undersized leaves. Another example is the last two trees in the table, one with 20% crown dieback and the second with 60% crown dieback and resultant DI's of 50 and 75 respectively. The tree with only 20% crown dieback has a high DI because of the foliar characteristics. However, if the subsequent growing season was favourable and the poor foliar conditions were not pathologically induced the foliage would likely recover and the DI the following year would then be much lower. The DI method can identify this rapid annual flucuation whereas such changes could go undetected or unquantified with assessment methods which use only branch characteristics or simply the presence or absence of foliage.

Looks Good, but is it Reproducable?

Although the DI appeared to have the attributes desired for the planned deciduous forest survey in Ontario it was still necessary to conduct a field trial to determine if the rating method was reproducable and to define confidence intervals. Ten trees representing a gradient of decline from perfectly healthly to dead were selected and sequentially numbered in woodlot a in southern Ontario. The ten test trees were scattered throughout the woodlot to such an extent that it was

necessary to have a flagging tape trail to get from tree to tree. Ten people were trained for several hours in the identification of deciduous tree decline symptoms as they are used in the DI methodology. They were then provided with the DI field templates and proceeded to rate each of the ten marked trees. When all the trees had been rated by each of the evaluators, the tree identification numbers were changed and the rating sequence was repeated. Each of the ten trees was rated by all evaluators five times, with the tree identification numbers changed between assessments.

The tree numbers were changed and the trees spread throughout the woodlot so that the evaluators would not become familiar with individual trees and therefore bias their rating.

A second set of five assessment runs was conducted on the ten test trees with paired evaluators. Two evaluators discussed the rating parameters for each tree, agreed on one score, and filled in one assessment form per tree. As in the first series of assessment runs, the tree identification numbers were changed between runs. The assessment teams were altered between each of the five paired assessment runs.

The field trial yielded 75 DI values for each test tree. These data are summarized in Table 2. It clearly shows that the DI is reproducable, even with different evaluators trained only for basic symptom identification. It also indicates that the paired assessment provides a slightly better resolution of decline gradient and in most cases a narrower confidence interval. The 99% confidence interval for the single-evaluator assessment ranged from 2.2 to 5.2 whereas the range was 1.4 to 4.5 for the paired assessment. Similarly, the coefficient of variation was lower with the paired assessment for all but the healthiest tree with the lowest DI. The coefficient of variation was inversely rated with DI. This is not surprising because the proportional difference in the DI between individual evaluations is greater with healthier trees relative to trees in a more advanced stage of decline. For example, a healthy tree with a mean DI of 4 may have a range from 2 to 6, whereas a declining tree with a mean DI of 40 may

have a range from 35 to 45. Proportionately the variation about the mean is much larger for the healthier tree even though the absolute difference is less.

How the Decline Index has been used in Ontario

1) Site Specific Studies

The DI method for assessing hardwood tree condition has been used at selected sites annually in the Muskoka area since 1984 and in the Peterborough area since 1985. Figure 1 is a histogram illustrating the mean annual DI for these two areas from 1984 to 1988. These data indicate that from 1984 to 1987 the condition of the hardwood forest at these sites was gradually improving. However, in 1988, as a result of high summer temperatures, drought and early season insect defoliation, the forest condition deteriorated significantly. Least significant difference analysis was used to confirm that relative to 1984 the apparent tree recovery and subsequent deterioration were statistically significant.

An examination of the individual rating parameters revealed that the increase in the DI in 1988 was driven by large percentage increases in foliar chlorosis and small leaf size and not an increase in branch dieback. This would suggest the deterioration is temporary and given favourable growing conditions in subsequent years a recovery is likely. Tree rating systems based solely on branch dieback or defoliation status would not have detected the 1988 episode.

2) Province Wide Survey

The DI was the primary assessment method used in a province wide hardwood decline survey conducted in 1986. One hundred and ten permanent observation plots were established across the Deciduous Forest Region of Ontario. Each plot contained 100 trees greater than 10 cm diameter at breast height. The DI was calculated for each tree and the mean DI was determined for each plot. Six DI ranges were

selected based on the mean DI frequency distribution. Figure 2 was prepared illustrating each of the 110 plots as one of the six DI classes.

These data suggested a regional pattern of tree condition across the province. Generally, the severity and extent of decline was worse in the south-west and the north-central portion of the range of sugar maple in Ontario. In contrast a band of low decline across south-central Ontario separated these two areas of higher decline. This pattern is better illustrated by calculating the mean DI of plots within nine recognized forest regions in the Province (see Figure 3). These forest regions are based on soil and climatic parameters. Using Least significant difference analysis, the mean DI's in Figure 3 must be different by at least 4.7 to be statistically significant at $p < 0.01$. Therefore the apparent pattern is partially confirmed, that is the deciduous forest in the north-central part of the province is in fact in poorer condition than the south-central area of Ontario. The other area of relatively high decline, the south-west, is not different based on least significant difference analysis. However, using another statistical testing procedure, K-means Cluster analysis, the plots in the south-west, like those in the north, were most frequently grouped as high decline plots.

Advantages of the DI Method

1. Quantitative: - descriptive statistics applicable.
2. Descriptive: - combines both foliar and branch characteristics.
3. High Resolution: - capable of distinguishing subtle changes across a wide gradient.
4. Reproducable: - tests indicate acceptable confidence intervals.
5. Flexible: - individual assessment parameters can be changed to reflect regional symptoms.
6. Fast: - no specialized equipment and an efficien tly designed field form yields rapid field assessment.

7. Non-specialized field crews: - field crews can be trained quickly to identify specific decline symptoms, no need to have forestry specialists.

8. Computer compatable: - assessment data lends itself to a spreadsheet-type handling system where only the various decline parameters need to be recorded in the field and the DI can be automatically calculated, thereby reducing data handling time and related error and facilitating descriptive statistics.

9. Standardization: - direct comparison between regions, states, provinces, countries etc. (providing assessment parameters have not been substantially altered).

Conclusions

The DI method of assessing deciduous tree decline has been used successfully in Ontario. Baseline data has been collected from a network of permanent observation plots. Subsequent surveys using the DI method will enable forest managers to identify changes in the condition of the province's hardwood forest and precisely where and to what extent any changes have occurred. The ability to accurately quantify temporal and spacial changes in forest tree condition is a vital component of any study into the effects of regional atmospheric pollutants or other stresses on a forest ecosystem.

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Table 1: A sample feild assessment form for 10 example trees ranging in condition from healthy to very severely declining.

Decline Classification	% Crown Dieback	Leaf Colour			Leaf Size		Decline Index
		Normal	Chlorotic		Normal	% Undersized	
			% Slight	% Significant			
healthy	0	X			X		0
healthy	0		10			10	4
light	0		30	10		20	11
light	10		10			10	13
moderate	10		30	20		20	22
moderate	20		10	10		10	25
severe	30		10	20		30	40
severe	40		10	10		20	45
very severe	20		20	60		80	50
very severe	60		20	40		90	74

Table 2: Results of feild trials to test the Decline Index for reproducability and to evaluate single and paired assessment.

Tree No. & Condition	Single Assessment* Mean Decline Index	Coeff. Var.	99% Con. Inter.	Paired Assessment** Mean Decline Index	Coeff. Var.	99% Con. Inter.
1. healthy	7	92%	2.2	2	165%	1.4
2. healthy	8	84%	2.2	8	49%	1.8
3. light decline	14	70%	3.2	13	35%	2.3
4. light decline	18	59%	3.6	17	54%	4.5
5. moderate decline	18	61%	3.8	21	38%	4.0
6. moderate decline	23	67%	5.2	23	40%	4.5
7. moderate decline	26	48%	4.4	26	21%	2.7
8. severe decline	29	31%	3.1	32	16%	2.6
9. severe decline	41	35%	4.8	45	12%	2.7

* tree assessment conducted by one person (total number of assessments per tree = 50, 5 times by 10 different people).

** tree assessment conducted by 2 people who together filled in one assessment form (total number of assessments per tree = 25, 5 times by 5 different 2-person crews).

Total number of individual tree trial assessments = 750.

* tree assessment conducted by one person (total number of assessments per tree = 50, 5 times by 10 different people).

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Total number of individual tree trial assessments = 750.

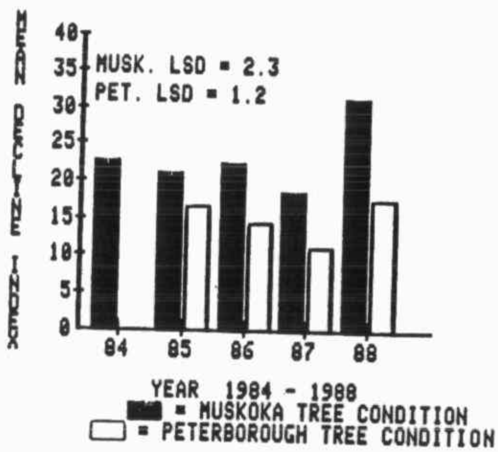


Figure 1: Mean annual Decline Index for test plots in the Muskoka and Peterborough areas of Ontario. LSD = Least Significant Difference.

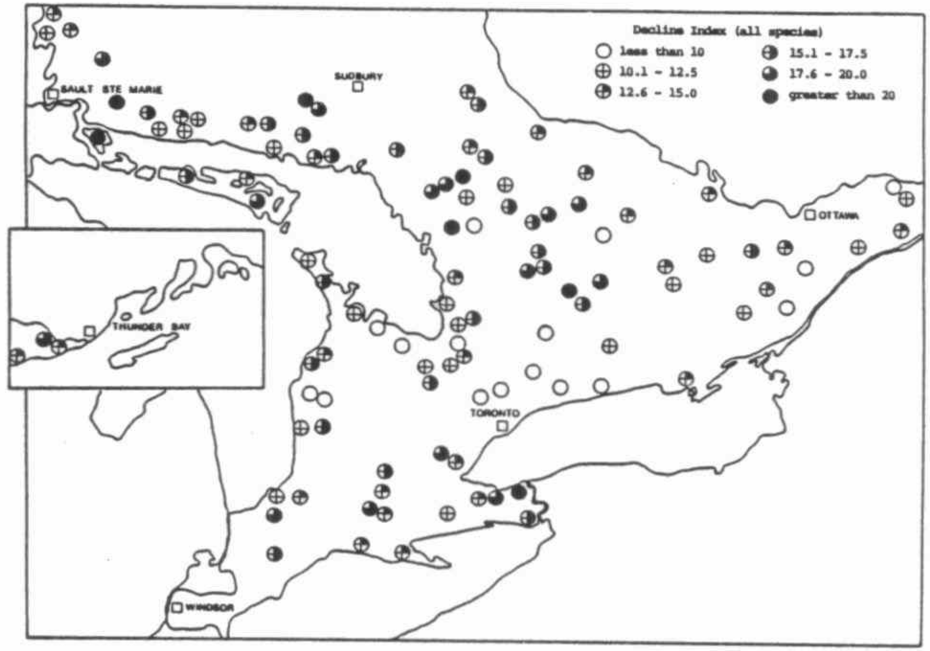


Figure 2: Mean Decline Index of 110 permanent forest observation plots, assessed in 1986.

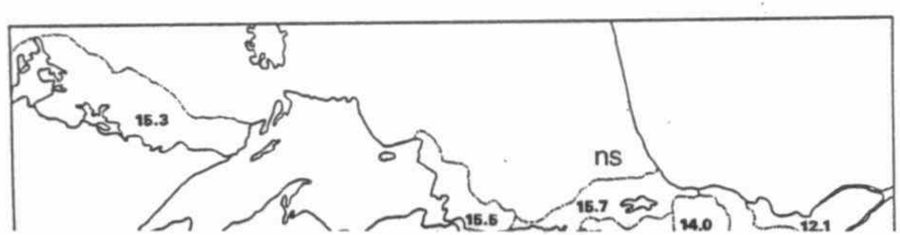
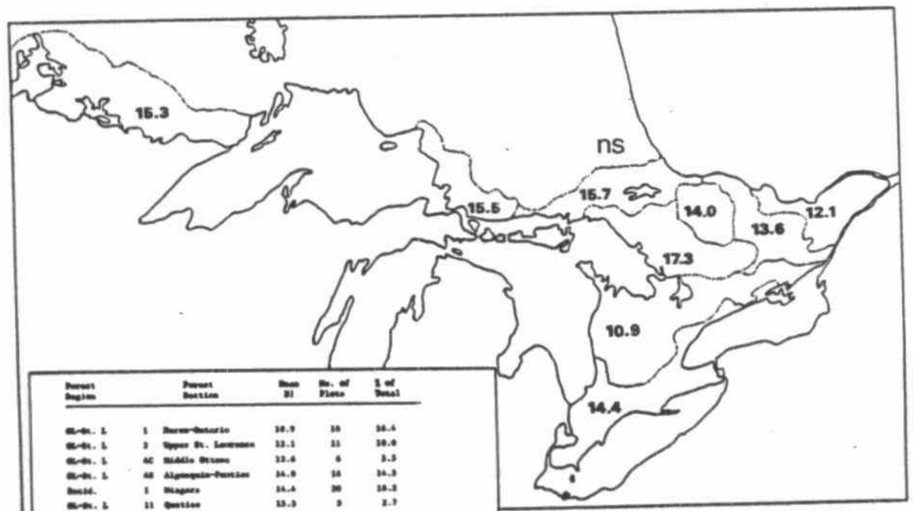


Figure 2: Mean Decline Index of 110 permanent forest observation plots, assessed in 1986.



Forest Region		Forest Section	Mean DI	No. of Plots	% of Total
GL-St. L	1	Huron-Ontario	10.9	18	16.4
GL-St. L	2	Upper St. Lawrence	12.1	11	10.0
GL-St. L	4C	Middle Ottawa	13.6	6	5.5
GL-St. L	4E	Algonquin-Pontiac	14.0	16	14.5
Decid.	1	Niagara	14.4	20	18.2
GL-St. L	11	Quetico	15.3	3	2.7
GL-St. L	10	Algoma	15.5	11	10.0
GL-St. L	4E	Sudbury-North Bay	15.7	13	11.8
GL-St. L	4D	Georgian Bay	17.3	12	10.9
Least Significant Difference (at α=0.01)			4.7		

forest classification after Rowe, 1972
ns region not surveyed

Figure 3: Mean Decline Index of 9 forest sections in Ontario, based on the 1986 assessment of 110 plots illustrated in Figure 2.